Ultrasonic Nondestructive Evaluation of Multilayered Structures

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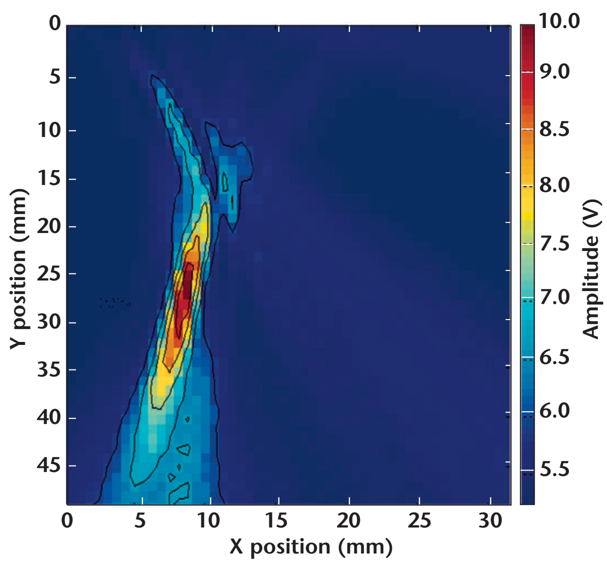
Multi-layered structures such as weapons assemblies and aircraft wings pose challenges for nondestructive evaluation (NDE) techniques—to detect a cracked ceramic or void in a multi-layered weapons system, for instance—because of inaccessible areas and close interfaces. We are developing two approaches for overcoming these difficulties: 1) guided-wave modes and 2) beam steering of bulk waves.

The first approach involves using the wave-guide structure of a multi-layered medium to send wave modes along the structure into inaccessible areas, and requires the ability to preferentially excite modes in which most of the energy exists in the layer of interest. A novel phased-array method is being developed under this project to find such guided-wave modes experimentally. Most guided-wave research has been limited to single layers, such as aluminum plates in aircraft or steel piping. Investigating guided waves in multilayered media will extend guided-wave techniques into many new applications.



An imaged section of an aluminum block with a 1-mm-diameter side-drilled hole obtained by a 20°-ultrasonic steered beam.

The second approach steers and focuses ultrasonic bulk waves into layers of interest to find voids in a sublayer. Steering the beam enables areas up to ~6 in. to be scanned from a single position. Focusing increases resolution and improves minimum flaw-size detection.

Our project will develop advanced technologies for inspecting weapons systems in support of LLNL's stockpile stewardship mission and will establish the science base for using guided-wave-based NDE for multilayered mesoscale targets.

In FY02, a model of guided-wave mode generation by phased array was developed. Results of analysis using this model showed the need to maximize array length, minimize the effect of element spacing, and maximize the number of elements. We then designed an array based on this analysis and used it to detect successfully a 30% through-wall notch in a 1/8-in.-thick aluminum plate, although sensitivity was ~33% less than that of traditional ultrasound.

We developed a software interface for steering a phased array of ultrasonic beams for single-layer media. In addition, a time-delay beam image reconstruction algorithm previously developed at LLNL for steered-beam data was modified and used to image a 1-mm-diameter hole in an aluminum block—achieving our goal of detecting flaws of 1 mm in diameter. The area of the block shown in the figure was imaged by focusing the 20°-off-axis beam at the center of the area.

In FY03, we will advance from single-layer to multilayered media and 1) perform proof-of-concept testing of guided waves and bulk waves for the NDE of multilayered structures by detecting programmed flaws in multilayered structures; 2) develop array input parameters for beam steering in multilayered media; 3) modify image reconstruction codes for multilayered media; and 4) improve axial distortion in images.